

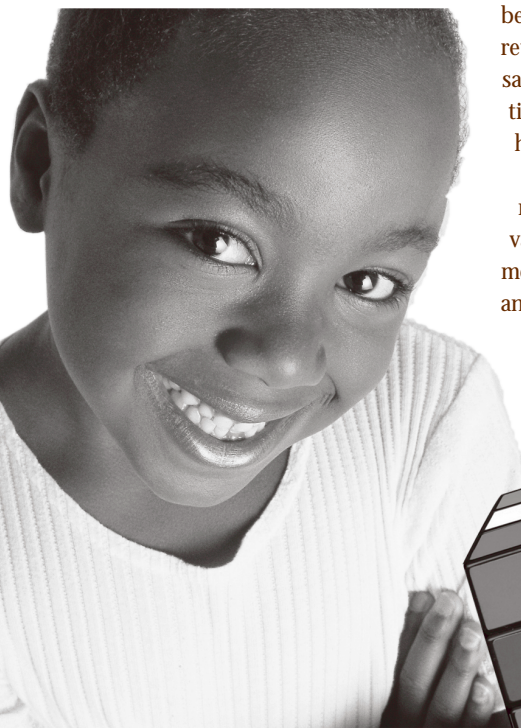
The All Begin as Scientists

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Scientists spend their days investigating the world and making sense of it. Their goal is to discover patterns and order that will lead to better explanations of phenomena. Indeed the nature of scientific inquiry shares some of the means and ends of the childhood games we played to satisfy our curiosity about “what’s going on out there.” We observed and experimented with how things work. The uncertainty introduced by changing conditions adds complexity to the ultimate aim of the game—to perfect our mental models of our surroundings, which as we grow older, are continuously expanding on time and spatial scales (*Holt, 1983*).

This essay and those that follow in future issues of *Research Education* intend to encourage students, educators and scientists to discuss their experiences in research projects and/or coursework where learning is taking place through the process of inquiry. With regard to applying this process in traditional science, mathematics, engineering and technology (SMET) coursework, some critics may ask: why have students spend time discovering what is already known (*Holt, 1983*)? Thus, these essays aim to motivate dialogue about the aspects of science inquiry that should be emphasized in SMET learning and practical ways to address them. In this first one, we focus on the use of models and observations in inquiry.

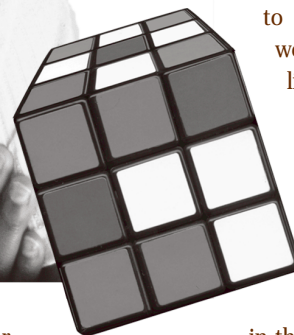
At an early age we begin to develop a scientific perspective, seeking to explain order in the world by using the tools of touching, hearing, smelling and seeing. By conducting self-



behavior of the earth system. Continuous retrieval of Earth images and data by NASA satellites and ground stations confirm assumptions that our planet is a complex system of human and natural processes.

Scientists have made significant advancements over the past two decades using observational data as inputs to develop computer models that simulate the earth’s atmosphere and oceans. By improving these models and running experiments where human-made and natural variables are changed to force possible scenarios in the system,

scientists hope to be able to predict what the world’s climate will be like in the future. For example, an experiment with increased greenhouse gases, compared to one with current levels, can help quantify change



in the climate system produced by natural variability and by human influence. The value added by this information to policy-making can result in better informed and justifiable decisions on legislative actions such as regulating clean air and water.

Engaging in this type of scientific endeavor requires scientists to look beyond the deterministic characteristics they discover about Earth’s physical, chemical and biological processes and study how they interact with the natural variability of our atmosphere and oceans to produce earth’s global and regional climate. It also demands the collective expertise of many disciplines to solve problems where the complexities of the system’s behav-

motivated experiments and observations or investigations guided by adults, we are provided with data to compare, contrast and deduce cause-and-effect relationships. How is this different from the way a physicist studies the world?

Armed with physical laws expressed in mathematical equations, physicists can explain natural phenomena such as how earth achieves energy balance, sustaining the habitability of our planet through diverse interactions of the sun’s energy with land surfaces and atmospheric components. Yet, the more scientists are able to explain the world and prove that deterministic forces drive it, the more they learn about the unpredictable or chaotic

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iors are interrelated (Gleick, 1987). Today, physicists, economists, engineers, political scientists and other scientists are making efforts to study Earth as a system. They believe that some day we will be able to explain and make predictions about this system with a significant degree of confidence using sophisticated climate models and observations from space and the planet's surface.

More and more results from modeling experiments are used in conjunction with observations to explain Earth's behavior, elevate an issue to the forefront of the national agenda, and justify decisions that impact our lives. Thus, we need to find effective ways to give citizens an appreciation of the Earth as a system, the models and observational data used to explain the system, and the capability and limitations of these tools. This is inherently linked to informed perspectives on widely discussed environmental issues, including concerns over health impacts due to local traffic and transportation patterns, and the regional/global

implications of changing patterns of land use resulting from human development.

Before we can understand change in a system, it is important to identify conditions that produce equilibrium or stability in that system. Both change and equilibrium are influenced by external conditions (system inputs) that are used in a model to study interactions and change (system outputs). In a model experiment that is run for many years into the future, the conditions (inputs) are based on observational data.

Understanding how Earth's conditions change is a matter of probability. When climate modelers run experiments, they look for conditions that "load the climate dice" and increase probability for global change and a world that may be warmer, cooler, wet-

ter or drier. Statistics are a mainstay of science used to explain the significance of change. In fact, developing the scientific capability to quantify past, recent and future global change

with a high degree of confidence enhances our capability for responsible decision-making. This is increasingly important as immediate costs and benefits of many policies to mitigate negative changes are likely to be borne unequally by citizens depending on where they live.

As science advances, we want all citizens to be able to understand new knowledge so we can evaluate public issues and societal responses to them responsibly. It seems beneficial to look at the process of science inquiry where this knowledge is generated, as well as at how young children learn, in seeking strategies that lead to this appreciation. Fundamental understanding of science inquiry begins in early childhood and can potentially form a sound foundation for a high level of life-long science literacy, interest and motivation. We have seen that children develop their own models and techniques for observation, seeking explanations of simple systems. Using models and observations to formulate, test and revise hypotheses about relationships, they begin to understand the phenomena encountered in daily life (Mandinach, 1989).

How we sustain this type of learning throughout our lives and ensure that it remains an important component of science learning from elementary to higher education levels is a challenge that the ICP collaboration among students, faculty and scientists is uniquely positioned to address. In spring 2000, we plan to host discussions lead by ICP faculty, on the idea of research education and to exchange best practices for its classroom implementation. We look forward to hearing all perspectives on this idea and creating a forum that benefits teaching and learning. ■

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